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UNDERWATER ACOUSTIC GENERATOR PHASE I SEA TRIAL, MARCH 1992

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Underwater Acoustic Generator Phase 2 Sea Trial, March 1992

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Abstract

In support of a joint ALO-SA, DSTO, and Industry program to develop a discrete low frequency towed underwater acoustic generator (UAG), a series of sea trials were conducted. These trials were conducted in the Gulf of St. Vincent and the sea west of Kangaroo Island to check the environmental and acoustic performance of a concept UAG. This report describes the UAG Phase 2 evaluation trial held in March 1992. Details and results of the trial are provided along with an assessment of the UAG performance and conclusions and recommendations for further development and tests.

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Underwater Acoustic Generator Phase 2 Sea Trial, March 1992

1. *Introduction*

As part of a joint ALO/DSTO program to develop a discrete low frequency continuous wave (CW) towable Underwater Acoustic Generator, the Maritime Operations Division (Salisbury), MRL and the ALO-SA awarded a contract for Phase 2 to a local SA company Resonance Technology Pty. Ltd.(RTPL) [1]. The contract was for the development and validation of a concept discrete low frequency CW towed underwater acoustic generator(UAG).

To evaluate and assess the performance of the concept UAG it was necessary to conduct a series of sea trials. The sea trial conducted aboard the South Australian Dept. of Fisheries (SADF) vessel the MRV Ngerin, on the 16 to 18 March 1992, was required to validate the acoustic and environmental performance of the concept UAG and provide supporting data for Phase 3, the design of a smaller more compact and efficient CW towable discrete low frequency generator(DLFG).

The trial was conducted in the Gulf of St. Vincent and the sea 35 n.mile west of Kangaroo Island.

2. *Objectives*

The main trial objective was to sea test the concept UAG system to confirm that it met the acoustic and environmental requirements of the technical requirement specification [2]. Tests were conducted to measure and record,

(a) the UAG Towed Generator Body (TGB) acoustic and environmental performance,

(b) operator ability to operate the system and set and maintain the required TGB towing depth by tow cable payout and/or retrieval as guided by the TGB depth sensors and onboard system control monitors and display.

2.1 *Primary Objectives*

(a) To measure and record the TGB source level and output harmonic content at selected operating frequencies towing depths and tow speeds.

(b) To conduct TGB tow tests to confirm correct operation of the system under specified environmental conditions.

2.2 *Secondary Objectives*

If time and conditions on site permit, measure and record the source level of a J9S deep submergence underwater acoustic reference projector in the same environment.

3. *Proposal*

In accordance with the Sea Trial Plan [3] it was proposed to tow the UAG towed generator body from a surface vessel to record the acoustic and environmental performance of the system at selected operating frequencies, tow depths, and tow speeds. In addition it was proposed to measure the tow characteristics of the towed generator body at various tow speeds, tow depths, and lengths of tow cable.

4. *Equipment Development*

4.1 *Requirement*

To achieve the above objectives it was necessary to,

(a) design and develop a concept UAG system which could be installed onboard and operated from a surface vessel subject to the necessary mechanical and electrical considerations being met,

(b) hire a surface vessel with the necessary equipment, facilities, and capability to conduct the trial.

A schematic of the concept UAG system is shown in Figure 1. The system was developed jointly by the Maritime Operations Division and Resonance Technology Pty Ltd (RTPL) in accordance with the technical requirement specification [2]. The main UAG subsystems are the System Controller (SC), Winch and Handling System (WHS), Tow Cable (TC), and Towed Generator Body (TGB). The functions and requirements of each subsystem are given in

the technical requirement specification. The SC, TGB and TGB deck cradle were supplied and operated by the contractor RTPL. The WHS, heavy duty deck cradle, TC, and all data recording and analysis equipment were supplied and operated by Maritime Operations Division personnel. The ALO-SA was responsible for the purchase of the 250 m of light weight Kevlar underwater TC [4].

As hire of a surface vessel was restricted to those locally available in SA for logistics reasons, the MRV Ngerin owned and operated by the South Australian Department of Fisheries (SADF) was chosen. Designed to carry out research for the SADF on fisheries and the aquatic environment of SA, this vessel was operated and maintained by a crew of four and provided accommodation for up to seven additional trials personnel.

4.2 *Design and Development*

From May 1990 to August 1991, MOD and RTPL personnel, assisted by staff from the ALO-SA,

(a) developed a concept demonstration UAG system,
(b) modified and adapted an existing WHS,
(c) specified,procured and tested 250 m of faired light weight Kevlar TC [4, 5],
(d) designed and built a heavy duty deck cradle which could be bolted to the ship's aft deck and carry the winch and TGB deck cradle,
(e) designed and supplied a 0.5 m diameter cable sheave,
(f) assembled and tested a data recording and analysis facility for use on board the trials ship and future shore base analysis,
(g) installed the above equipment onboard the trials ship,
(h) planned and initiated the sea trial(s),
(i) planned and conducted tow stability trials on the UAG ballasted TGB in the Gulf of St Vincent and sea west of Kangaroo Island [6]

5. *Conduct of Trial*

5.1 *Trial Schedule*

The trial was scheduled for and held in the period 16 to 18 March 1992. To reduce risk and avoid the possible waste of sea time, it was proposed in the Sea Trial Plan [3] that two preliminary trials be conducted at sites A (Port Adelaide River channel) and B (Gulf of St Vincent) prior to the main deep water trial at Site C 35 n.mile west of Kangaroo Island as shown in Figure 2.

The first preliminary trial covering the installation and set to work was successfully completed onboard the MRV Ngerin at Site A alongside the SADF wharf Port Adelaide, on Monday 16 March 1992. This was followed by the second preliminary trial, referred to as the shallow water shakedown trial in the Sea Trial Plan [3], at Site B in the Gulf of St Vincent on Tuesday 17 March 1992. The main

deep water acoustic trial was then conducted at site C on Wednesday 18 March 1992 prior to the ship returning to Pt Adelaide on Thursday 19 March 1992.

5.2 *Deployed Configuration*

The configuration deployed for the shallow water shakedown trial was as shown in Figure 3. UAG TGB sound pressure data were gathered at a nominal tow speed of 3 knots and TGB depth of 15 metres from a S4009 hydrophone system attached to the UAG TC. To avoid possible saturation of the hydrophone system, the S4009 hydrophone was placed 10 m from the centre of the UAG TGB piston diaphragm.

The same configuration was used for the deep water trial where UAG sound pressure data were recorded at nominal tow speeds of 2, 3, 6 knots and respective towing depths of 90, 50, 42 metres. For reasons given in section 5.4 the J9S deep submergence projector was not deployed.

5.3 *Tow State*

The same tow configuration as discussed in section 5.2 and shown in Figure 3 was used for both the shallow and deep water trials. Plastic cable ties were used to attach the hydrophone cable to the UAG TC during deployment of the TGB while the TGB depth was maintained by operator retrieval and deployment of the TC during the trial. Except for one slow 2 knot deep water turn, straight line tows only were made when the TGB was deployed.

5.4 *Equipment Performance*

In general the UAG equipment operated satisfactorily throughout the trial however a "water in piston" fault occurred and several other intermittent problems were encountered.

The "water in piston" fault occurred during the shallow water shakedown trial when the tow speed was first increased from 3 to 6 knots. Immediately this happened the fail safe feature of the UAG system shut down the TGB and stopped it transmitting. After several unsuccessful attempts to restart the system, the TGB was winched aboard and secured in the TGB deck cradle. It was then dismantled and drained of approximately 2 to 3 litres of sea water. A careful inspection showed the o-ring seal for the 10mm hole connecting the piston and bladder air spaces had leaked. This was temporarily repaired with masking tape and the main deep water trial was later conducted without further incident although no further shallow water data were recorded owing to loss of time and the need to obtain deep water UAG TGB acoustic data.

In the longer term it was the intermittent problems which ultimately degraded the operational reliability of the UAG system until it could not operate continuously for more than 10 minutes before it stopped and had to be reset. Electrical interference was thought to be the main problem as the rate of failure increased as the UAG TGB source level was increased and the familiar "Bad Ack",

"Current Limit", and "TGB Time Out" error messages appeared on the screen of the remote PC controller.

As a result of the above, and the deteriorating conditions, the J9S deep submergence reference projector was not tested. Meanwhile the S4009 hydrophone system and associated data recording and analysis equipment proved to be adequate and reliable.

6. Test Results

6.1 Transportability and Mechanical Handling

The transportability and mechanical handling aspects of the UAG system were well demonstrated during the equipment transport, installation, trial, and removal stages.

On Monday 16 March 1992 the equipment was transported from DSTO Salisbury by workshop van and trailer to the ship at Pt.Adelaide where the ship's Hyab hydraulic sea crane was used to lift it aboard (see Figure 1). The large heavy duty deck cradle was bolted to the aft deck at four pre-existing bolt points centred about the ship's fore/aft centre line. The 1 tonne winch and TGB deck cradle were then bolted to the heavy duty deck cradle at preset positions with the cradle fixed slightly astern of the winch to facilitate the deployment and recovery of the TGB over the stern using the forward mounted Hyab and DSTO supplied sheave. The other UAG equipment including the SC main control rack and remote PC controller were man handled into the ship's wet laboratory and secured along with the data recording and analysis equipment.

Tow body deployment and recovery techniques used during the trial period proved to be adequate in moderate conditions up to and including sea state 3. Lateral movement of the TGB was controlled during recovery and deployment via lines attached to the two TGB fins. These were left trailing during the towing trials. By coordinating the working of these attached lines and the crane jib movement, the amount of TGB swing experienced during deployment and recovery was controlled. General observation however suggests that for deployment and recovery of the TGB in higher sea states the same techniques would be unsafe.

After the trial all UAG and other DSTO recording and analysis equipment were removed from the ship and returned undamaged to DSTO Salisbury.

6.2 Environmental Performance

The sea trial confirmed the TGB and faired light weight Kevlar TC have very stable towing characteristics throughout the specified 2 to 6 knot and 10 to 100m operating tow speed and depth ranges. The results listed in Table 1 show the operator had little trouble setting and maintaining stable tows over the above operating ranges in sea state 3 conditions and nominal TGB towing depths of 15, 42, 50, and 90 m. Furthermore the TGB depth variations listed in Table 1 meet the

± 2 m requirement specified in Reference 2 for a ship operating in sea state 0 given the swell height varied between 1 m and 2 m and was in phase with the TGB depth variations.

Table 1: Underwater acoustic generator, towed generator body tow characteristics

Tow Speed (kn)	Towed Generator Body Depth (m)	Towed Cable Length (m)	Water Depth (m)	Position	
				Lat	Long
2	90 ± 3	200	130	35°51'S	136°E
3	15 ± 1	25	30	34°52'S	138°5'E
3	50 ± 2	130	130	35°50'S	136°5'E
6	42 ± 2	200	130	35°51'S	135°58'E

Except for operational performance i.e. the ability to operate continuously at the design target source level for a period of not less than 20 hours, the Phase 2 concept UAG system was found to meet all major environmental requirements including, operating hydrostatic pressure (depth), tow speed, and tow stability. Surface water temperatures on trial ranged from 21°C in the Gulf of St Vincent (34°52'S 138°5'E) to as low as 17°C in the seas west of Kangaroo Island (35°51'S 136°E). The water temperature at each TGB depth was not recorded.

6.3 Acoustic Performance

The results of all in sea water UAG sound pressure level measurements made at site B in the Gulf of St Vincent and site C west of Kangaroo Island using a S4009 hydrophone placed 10 m away from the centre of the TGB piston diaphragm are shown in Figures 4 to 10 for fundamental transmit frequencies of 20, 28, 40, 63, 100, 220, and 500 Hz. Each figure shows the in sea water sound pressure spectra corresponding to the output power spectrum of the S4009 hydrophone. The top three spectrum of each figure were recorded at site C and respective towing speeds of 2, 3, 6 knots and nominal TGB depths of 90, 50, 42 m. In contrast the bottom spectrum of each figure are for site B tow speed 3 knots TGB depth 15 m.

6.3.1 Frequency Range and Stability

The intended operating frequency range of the UAG system was 20 Hz to 500 Hz selectable as a single frequency with resolution of 0.1 Hz. As it was unrealistic to test every discrete transmit frequency only those frequencies mention above were tried.

Varying degrees of spectral broadening are evident in most of the recorded in water TGB sound pressure spectra. This cyclic frequency shift appears to be caused by variations in the speed of the TGB piston's rotating spool valve brought about by load and torque variations in the mechanical drive chain. Since the spool

valve contains seven slot sets the TGB fundamental transmit frequency is seven times the frequency of spool rotation. The result is the frequency of rotation of the spool valve frequency modulates the higher fundamental transmit frequency and thus appears as sidebands spaced at integer multiples of the modulating frequency above and below the fundamental transmit frequency and its harmonics.

6.3.2 *Source Level*

Table 2 contains a summary of the in sea water rms sound pressure level (SPL) measured 10 m from the TGB piston for each fundamental transmit frequency, tow state and test site. All values were obtained from the corresponding in water sound pressure spectra shown in Figures 4 to 10. The values shown in brackets are the corresponding TGB peak piston accelerations (expressed in *g*s) recorded during each trial where:

$$\text{Peak Piston Accel}_{[gs]} \times 9.8_{[m/s/s]} = -\omega^2 \times \text{Peak Piston Displacement}_{[m]}$$

$$\text{where } \omega = 2\pi \times \text{Fundamental Transmit Frequency}_{[Hz]}$$

Table 2: *Sound Pressure Level (SPL) 10 m from underwater acoustic generator, towed generator body*

Frequency (Hz)	SPL dB re 1 μPa Tow speed = 2 kn TGB depth = 90 m Water depth = 130 m Test Site = * C	= 3 kn = 50 m = 130 m = * C	= 6 kn = 42 m = 130 m = * C	= 3 kn = 15 m = 30 m = ** B
20	150 (3 *g*)	150 (3 *g*)	151 (4 *g*)	152 (4 *g*)
28	149 (3 *g*)	153 (8 *g*)	151 (6 *g*)	157 (8 *g*)
40	158 (14 *g*)	159 (16 *g*)	160 (16 *g*)	161 (16 *g*)
63	161 (16 *g*)	162 (16 *g*)	161 (16 *g*)	165 (16 *g*)
100	167 (16 *g*)	166 (16 *g*)	165 (16 *g*)	163 (16 *g*)
220	164 (9 *g*)	162 (10 *g*)	162 (10 *g*)	162 (10 *g*)
500	152 (?? *g*)	151 (?? *g*)	151 (?? *g*)	155 (10 *g*)

*C = Deep water West of Kangaroo Island (35°51'S 136°E)
**B = Shallow water Gulf of St Vincent (34°52'S 138°5'E)
??*g* = Intermittent reading UAG TGB peak piston acceleration not recorded

As the results of Table 2 show, when the TGB was operated in 130 m of water (site C) at fixed frequency and constant peak piston acceleration, the SPL measured at a nominal distance of 10 m from the centre of the TGB piston diaphragm remained reasonably constant with tow speed and depth confirming the TGB passive depth compensation and internal piston plate and vibrating cylinder locating spring systems were working correctly. Both systems

compensate for static pressure variations caused by changes in the TGB operating depth and tow speed.

In shallow water the stronger interference effects of multiple ray paths from the surface and bottom were more significant than at the deep water site C and as expected the received sound pressure levels 10 m from the TGB sound source were up to 5 dB different from the comparable deep water results shown in Table 2.

From knowledge of the received sound pressure level 10 m from the TGB and the underwater sound propagation loss(Proploss) between the TGB source and S4009 hydrophone receiver, the UAG source level 1m from the TGB sound source can be calculated using the following relationship:

$$\text{UAG Source Level}_{[\text{dB re } 1\mu\text{Pa}]} = \text{SPL 10 m from TGB}_{[\text{dB re } 1\mu\text{Pa}]} + \text{Proploss}_{[\text{dB re } 1\mu\text{Pa}]}$$

The UAG TGB source levels can thus be calculated by adding the Proploss values calculated in Appendix A Table A-1 to the corresponding SPL of Table 2. These source levels are listed in Table 3 alongside their theoretical counterparts which were calculated using the AJRAYPLT model discussed in Appendix A assuming a sound source of constant volume velocity operating in a free space with radius and peak piston acceleration equal to the UAG TGB piston radius and the corresponding TGB peak piston accelerations given in Table 2. By way of a cross check the same theoretical UAG TGB source levels were calculated using the formulae derived by Carpenter and Farmer in Appendix 1, Reference 7.

Table 3: Underwater acoustic generator, towed generator body source level

Frequency (Hz)	Source Level dB re 1µPa @ 1m							
	Tow Speed = 2kn TGB depth = 90m REC depth = 85m Water depth = 130m		= 3kn = 50m = 46m = 130m		= 6kn = 42m = 40m = 130m		= 3kn = 15m = 9m = 30m	
	TRL	THE	TRL	THE	TRL	THE	TRL	THE
20	170	160	170	160	172	163	173	163
28	170	160	173	169	170	166	179	169
40	178	174	179	175	181	175	178	175
63	182	175	182	175	182	175	182	175
100	188	175	186	175	185	175	186	175
220	185	170	183	171	182	171	184	171
500	173	??	172	??	172	??	178	171

TRL = Corrected TRIAL results
THE = THEORETICAL UAG TGB Source Levels
?? = UAG TGB peak piston acceleration not known (refer Table 2)

The corrected UAG TGB source levels shown in Table 3 clearly indicate the UAG had no trouble achieving the design target source levels of not less than 180 dB re 1 µPa in the 40 Hz to 100 Hz frequency band, and 160 dB re 1 µPa in the 20 Hz to 40 Hz and 100 Hz to 500 Hz frequency bands. However these source

levels appear to be higher than their theoretical counterparts. For example at 20 Hz the corrected trial results are 10 dB high. At 28, 40, and 63 Hz they are up to [illegible] dB high, and between 10 dB and 15 dB high at 100 Hz and 220 Hz. The one value recorded in shallow water at 500 Hz was also 6 dB too high.

No complete explanation has been found for these rather large errors although a post trials investigation by the contractor of the TGB piston acceleration measurement technique used has discovered a software timing error which may have caused all recorded TGB peak acceleration measurements to be less than their true values. This was especially true for frequencies greater than or equal to 100 Hz where the corresponding error increased with frequency and has been estimated to range from 1 to 3 dB at 100 Hz up to 20 to 30 dB at 500 Hz. For frequencies less than 100 Hz, the higher than expected source levels recorded on trial may have been produced by the in-phase combination, at the S4009 hydrophone, of the in water sound pressure wave and a high amplitude vibration induced pressure wave propagating along the TC from the TGB source. Further testing will need to be undertaken to investigate if this was true and to determine if the receiving hydrophone needs to be vibration isolated from the TC.

6.3.3 Harmonic Content

The output harmonic content performance of the UAG TGB as measured by the relative difference between the in water SPL of the fundamental transmit frequency and harmonics is summarised in Table 4 for the deep water tests only. The shallow water results have not been listed owing to the uncertainty of the Proploss at each harmonic frequency and only the first four harmonics have been shown as these generally include those harmonics with the highest relative acoustic outputs. Where the harmonic SPL recorded was lower than the fundamental SPL the relative values entered in Table 4 are shown with a minus sign as a precusor and vice versa.

The shaded cells of Table 4 highlight instances where the UAG TGB did not meet the specified harmonic content performance which required the SPL of all harmonics to be not less than 10 dB below the SPL of the fundamental transmit frequency for frequencies ranging from 20 Hz to 100 Hz and, not less than 5 dB below for transmit frequencies greater than 100 Hz but less than or equal to 500 Hz. For fundamental transmit frequencies of 20, 28 and 40 Hz the UAG TGB definitely did not meet the specified harmonic content performance. However, for fundamental transmit frequencies of 63, 100, 220, 500 Hz it did. This can probably be attributed to the internal UAG TGB high power vibration generator and hydraulic supply system which controls the piston displacement and hence drive displacement harmonic content. In general the relative SPL of the even harmonics were well below their associated odd harmonics which suggests the mark/space ratio of the piston displacement waveform remained reasonably constant and close to one. On the other hand the relative SPL of the odd harmonics was high confirming the piston displacement waveform was not sinusoidal, particularly at the lower transmit frequencies.

Table 4: Underwater acoustic generator, towed generator body harmonic content

Frequency (Hz)	Harmonic	Harmonic SPL relative to Fundamental (dB)		
		Tow Speed = 2 kn TGB depth = 90 m REC depth = 85 m Water depth = 130 m	= 3 kn = 50 m = 46 m = 130 m	= 6 kn = 42 m = 40 m = 130 m
20	2	-20	-15	-15
	3	+8	+9	+9
	4	+2	-4	-13
	5	+12	-5	+2
28	2	-19	-10	-8
	3	+14	+10	+8
	4	-21	-3	-7
	5	+3	+4	+3
40	2	-11	-16	-21
	3	+5	-2	-4
	4	-13	-22	-25
	5	-4	-3	-9
63	2	-28	-23	-19
	3	-27	-12	-13
	4	-22	-22	-26
	5	-18	-12	-12
100	2	-35	-27	-27
	3	-19	-11	-20
	4	-27	-20	-33
	5	-20	-24	-29
220	2	-25	-34	-23
	3	-15	-23	-19
	4	-28	-37	-36
500	2	-32	-23	-23
	3	-5	-6	-8
	4	-25	-31	-18

7. Conclusions

The data recorded on the March 1992 UAG sea trial were sufficient to satisfy all of the primary test objectives. In particular analysis of this data has shown the Phase 2 concept UAG satisfies most of the performance and environmental requirements of the Technical Requirement Specification [2] except for operational reliability and harmonic content performance. Based on observations made during the trial and analysis of the recorded data it has been shown;

(a) the Phase 2 concept UAG TGB and TC have very stable towing characteristics when operated in seas up to sea state 3 and over the specified 10 m to 100 m and 2 kn to 6 kn operating depth and towing speed ranges. Furthermore the operator had little trouble setting and maintaining stable tows within this operating window.

(b) the transportability and mechanical handling aspects of the UAG system were adequate for installation onboard vessels of opportunity subject to the necessary electrical and mechanical requirements being met. However, general observation suggests that for deployment and recovery of the UAG TGB over the stern a safer mechanism would be required.

(c) the UAG TGB easily achieved the design target source levels of 180 db re 1 μPa in the 40 Hz to 100 Hz frequency band and 160 dB re 1 μPa in the 20 Hz to 40 Hz and 100 Hz to 500 Hz bands.

(d) the frequency stability and output harmonic content of the UAG TGB may be cause for concern, particularly at the lower frequencies where the harmonic spectral lines within the frequency range 20 Hz to 40 Hz were up to 10 dB higher than the fundamental and the effects of spectral broadening due to possible speed variations in the UAG TGB piston's spool valve were most noticeable.

(e) the present operational reliability of the Phase 2 concept UAG system does not meet the specified requirement. During the course of the trial the UAG system reliability degraded to the point where the mean time between breakdowns was 10 minutes and the trial had to be stopped.

8. Recommendations

Based on the results of the trial and conclusions above, it is recommended that:

(a) the Phase 2 concept UAG system be accepted as suitable for further development.

(b) a UAG system reliability improvement program be established to investigate and fix the problems contributing to the currently poor operational performance.

(c) further long term tank tests be conducted to assess the reliability of the "improved" UAG system prior to any future sea trials.

(d) an investigation be made to establish why the measured source levels were higher than theoretical source levels and a further sea trial be held to confirm the findings.

(e) the high harmonic content of the UAG TGB acoustic output be investigated and the problems occurring at the lower fundamental transmit frequencies be resolved.

(f) a suitable handling mechanism be designed and developed to enable the UAG TGB to be safely deployed and retrieved over the stern or side before allowing the UAG system to be used on an extended sea trial.

9. Acknowledgements

The assistance of the members of the trials team and the captain and crew of the MRV Ngerin for their part in the trial is gratefully acknowledged.

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Appendix A

Calculation of Proploss

In an ideal homogeneous isotropic unbounded free field environment the underwater sound Proploss would be equal to 20 $\log_{10}$(source to receiver spacing in metres). However, as this was not strictly the case for either the deep water or shallow water UAG acoustic trials, two underwater propagation loss models, the AJRAYPLT [8] and the STOKES [9], were used to calculate the Proploss.

The AJRAYPLT is a simple ray-type model based on rays that pass from source to receiver in isospeed water with specular reflection at both the surface and bottom where the bottom absorption is assumed to be independent of grazing angle and frequency. The model assumes a sound source of constant volume velocity due to a specified piston radius and piston displacement at each frequency. Fully coherent addition of sound pressure due to all rays is assumed.

The AJRAYPLT Proploss values computed for the UAG system trial are listed in Table 3 for a TGB piston radius of 0.142 m and peak piston accelerations equal to the corresponding g values shown in brackets in Table 2. These computed propagation loss calculations typically include more than 80 rays these having the least number of bottom bounces. A bottom loss corresponding to a pressure amplitude reflection coefficient of 0.7 was assumed. Source and receiver depths used were as listed in the table for a horizontal source receiver separation distance of 10 m. In each case the velocity of sound in water was assumed to be 1500 m/s and the density of water was taken to be 1000 kg/m^3.

In contrast the STOKES model is a shallow water modal propagation model which calculates the normal-mode-sum solution of the wave equation for an arbitrary sound speed profile in a water column with a sea bed consisting of a layer and a half-space. Intended primarily for use with source to receiver ranges greater than 500 m, the branch-line-integral feature was used to achieve improved calculations of the Proploss values at the shorter source to receiver ranges of the UAG trial. An isospeed (1500m/s) water column with a hard clay bottom and the same AJRAYPLT source and receiver depths and horizontal separation distances was assumed.

The Proploss values computed by the STOKES model for the concept UAG trial are listed in Table A-1 alongside their AJRAYPLT counterparts for comparison.

From the results listed in Table A-1 it can be seen the AJRAYPLT and STOKES Proploss values are generally not the same. In 130 m of water the AJRAYPLT model consistently gave results which were 20 ± 1 dB i.e. within 1 dB of those expected of a point source operating in a free field environment in which spherical spreading applies. By comparison the STOKES model produced Proploss values which ranged from as low as 6 dB to as high as 22 dB. In 30 m of water the AJRAYPLT model results were 20 ± 3 dB i.e. within ± 3 dB of those expected of a point source operating in a free field environment in which spherical spreading applies whereas the values calculated by STOKES were not.

Table A-1: Theoretical Sound Propagation Loss (PROPLOSS). UAG TGB source to S4009 hydrophone receiver (horizontal range TGB source to S4009 receiver = 10 m)

Frequency (Hz)	PROPLOSS dB re 1µPa							
	Tow Speed = 2kn TGB depth = 90m REC depth = 85m Water depth = 130m		= 3kn = 50m = 46m = 130m		= 6kn = 42m = 40m = 130m		= 3kn = 15m = 9m = 30m	
	AJR	STKs	AJR	STKs	AJR	STKs	AJR	STKs
20	20	19	20	6	21	6	21	18
28	21	16	20	22	19	16	22	20
40	20	19	20	20	21	18	17	25
63	21	15	20	16	21	16	17	17
100	21	14	20	16	20	14	23	14
220	21	9	21	10	20	10	22	9
500	21	6	21	7	21	11	23	7

AJR = AJRAYPLT values correct to the nearest dB
STKs = STOKES values correct to the nearest dB

As a Proploss of less than 10 dB over a source to receiver range of 10 m could only be achieved with the unlikely simultaneous in-phase combination of at least 3 to 4 rays each of the same presure amplitude as the direct path then it would seem the STOKES model can not cope with this short range source to receiver geometry. It would therefore appear that for short ranges the AJRAYPLT model is best and the Proploss values so calculated should be used to calculate the UAG TGB source levels.

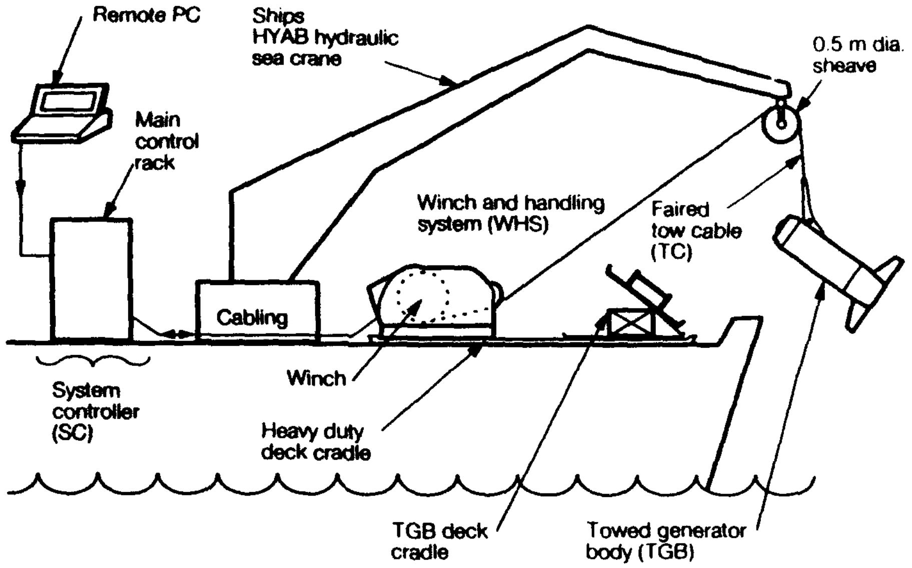

Figure 1: UAG System Schematic.

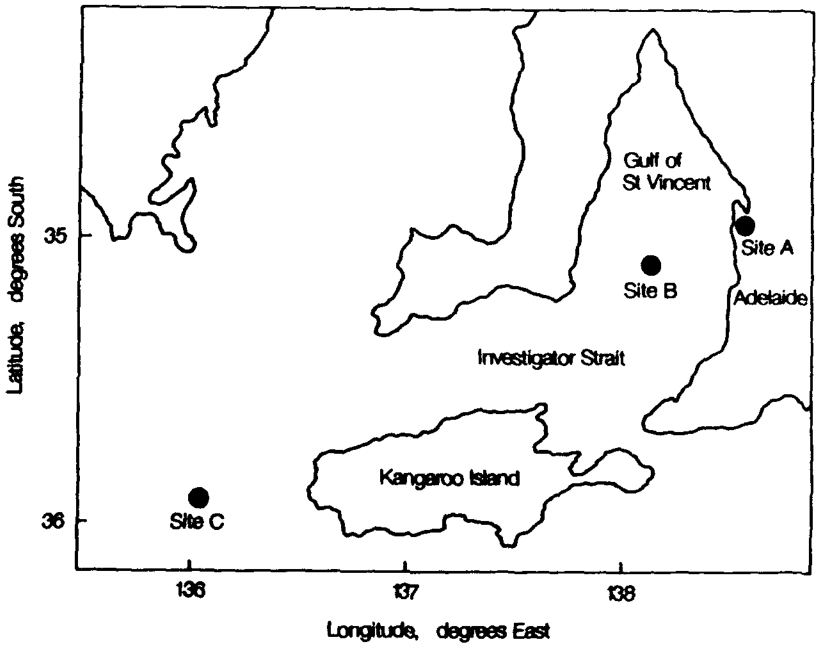

Figure 2: Trial Sites.

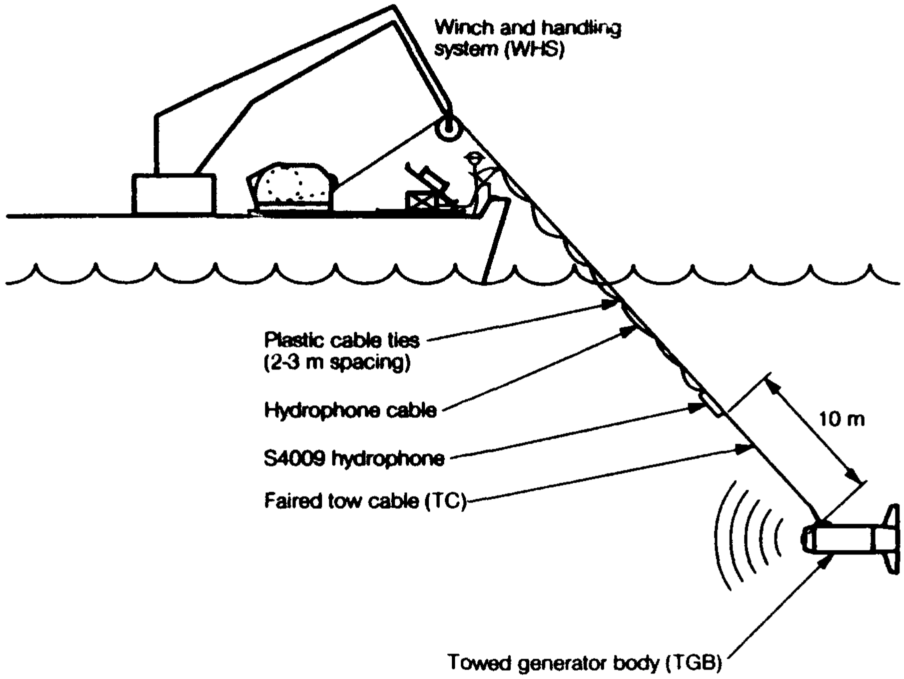

Figure 3: UAG System Trial Configuration

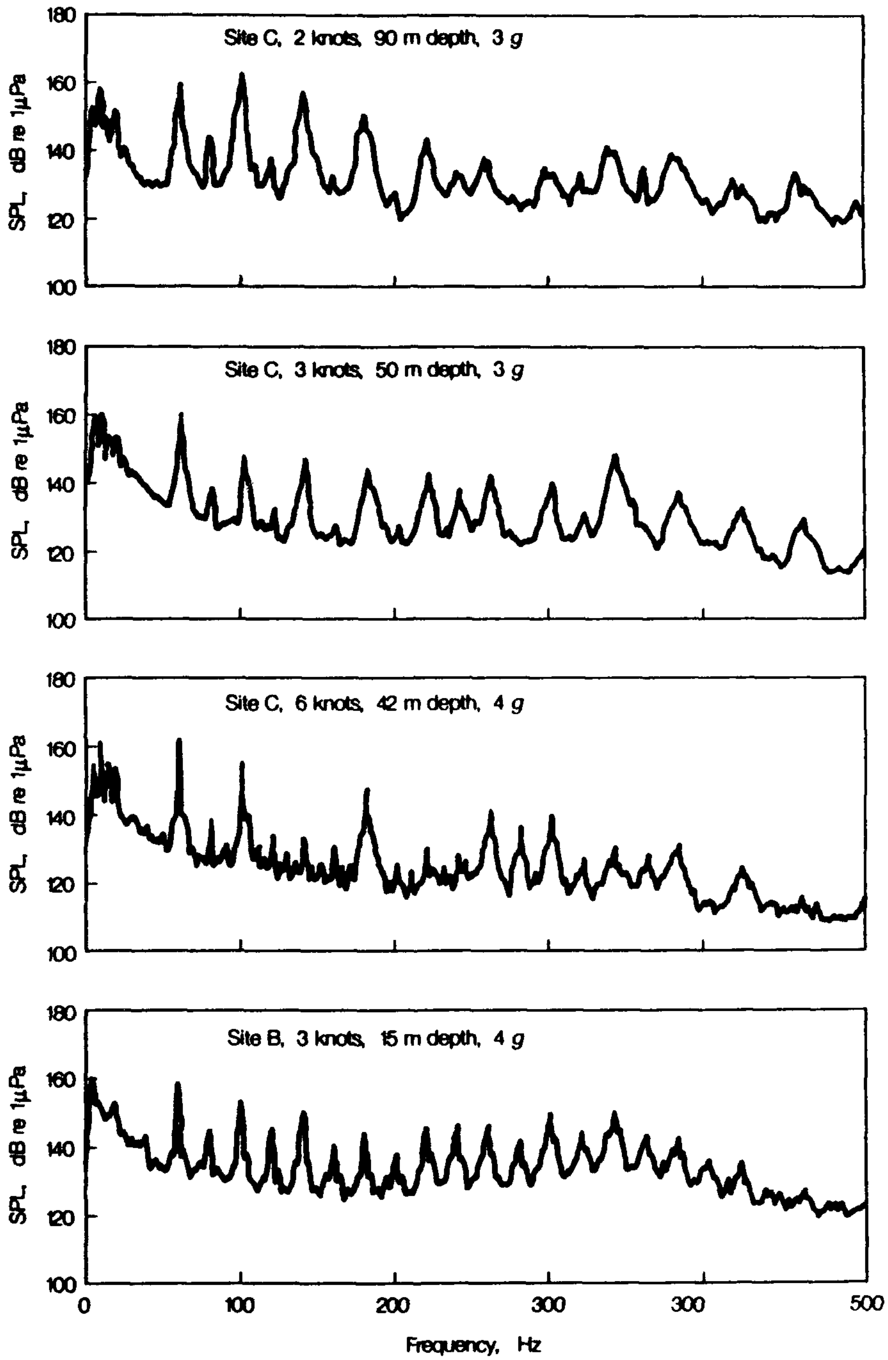

Figure 4: *20 Hz Sound Pressure Spectra (10 m from UAG TGB)*

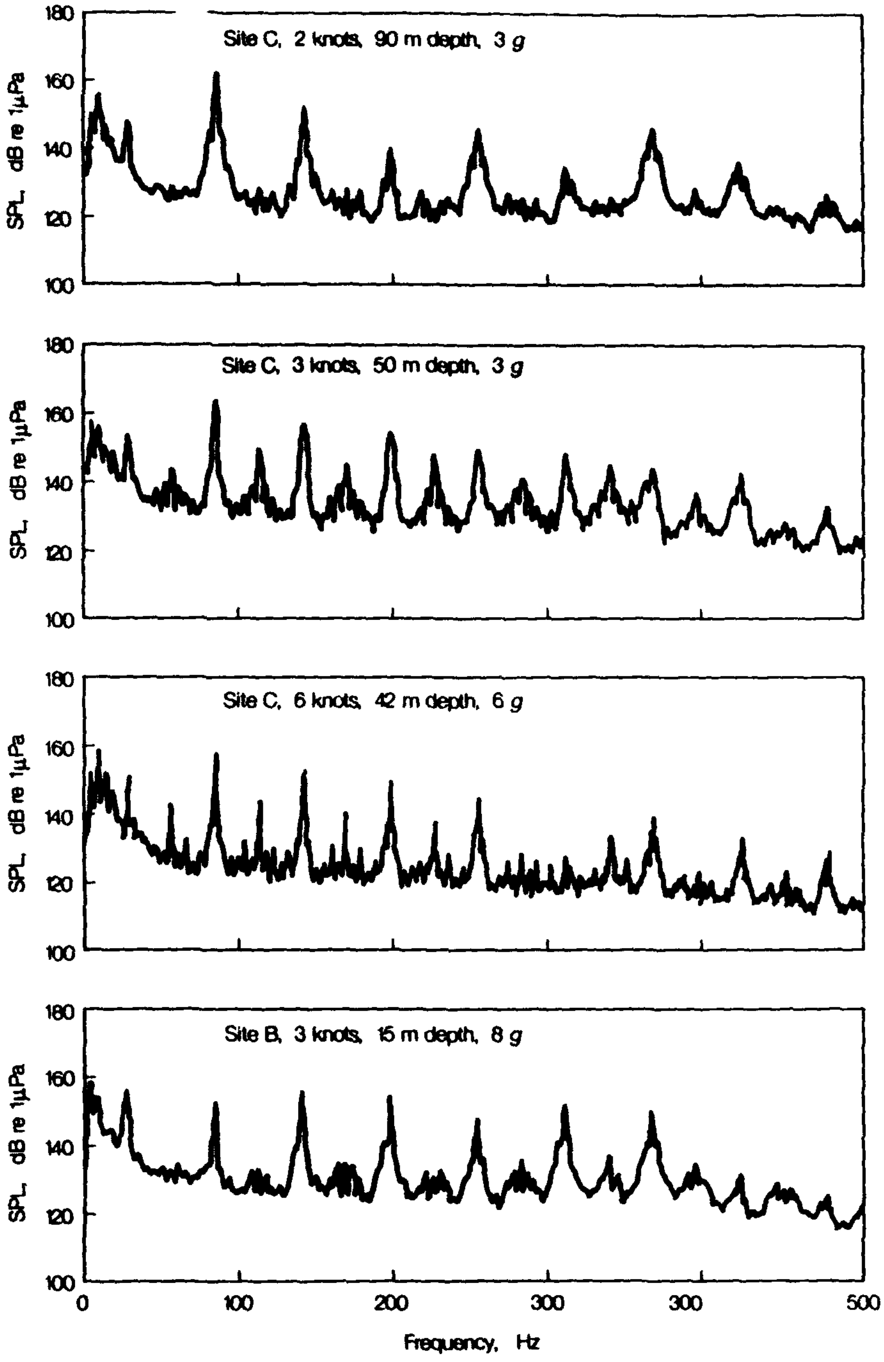

Figure 5: 28 Hz Sound Pressure Spectra (10m from UAG TGB)

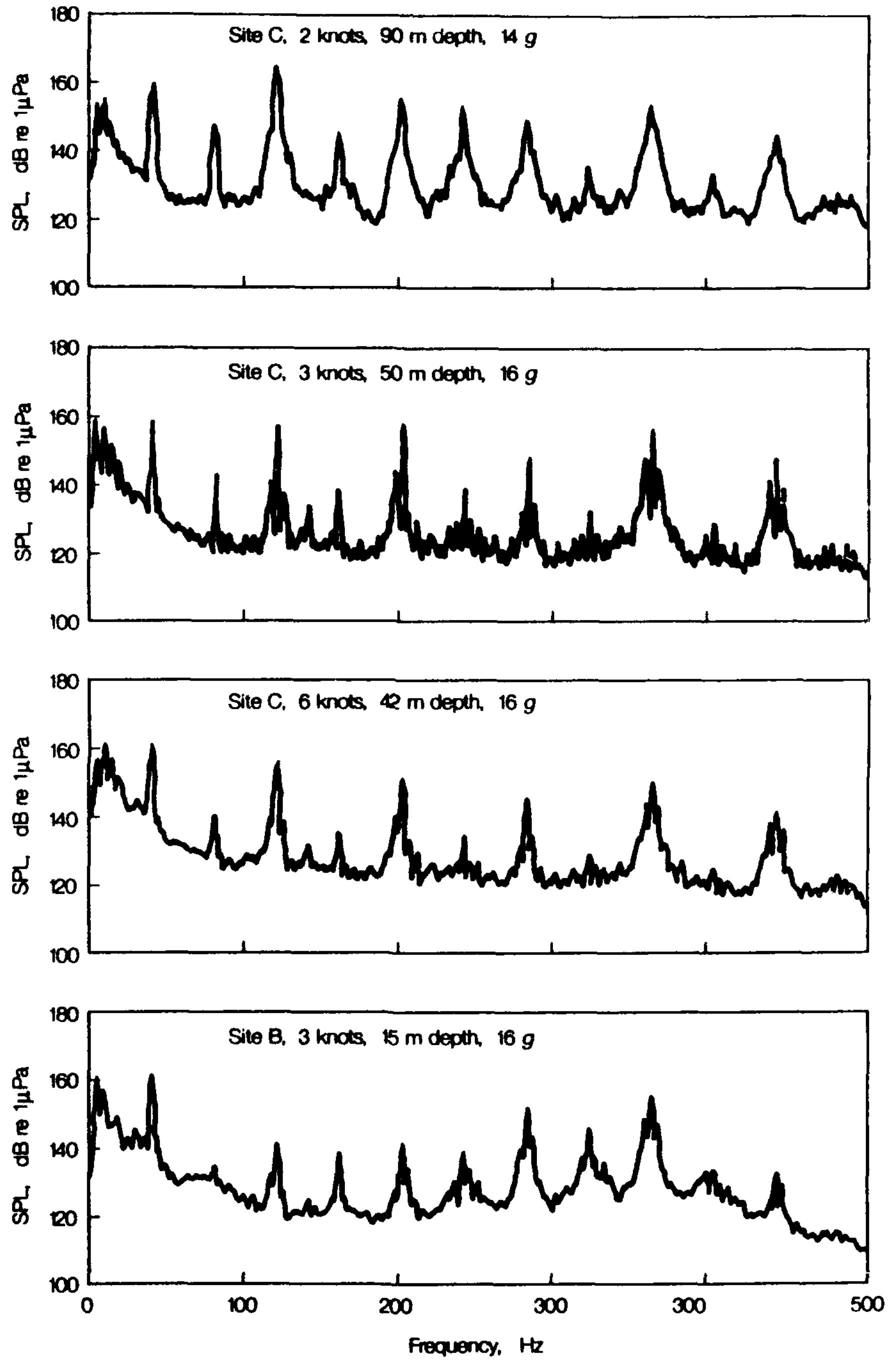

Figure 6: 40 Hz Sound Pressure Spectra (10m from UAG TGB)

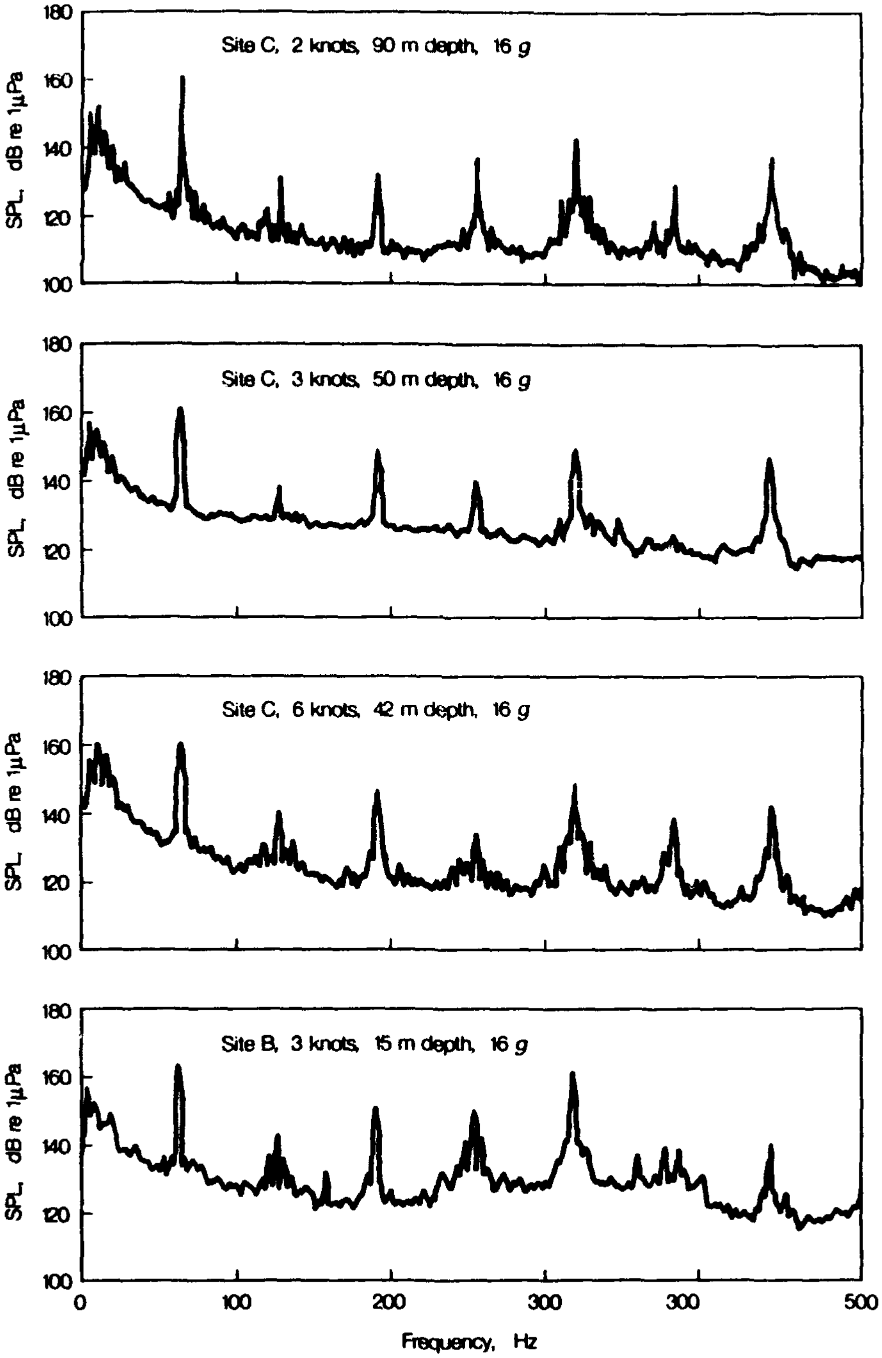

Figure 7: 63 Hz Sound Pressure Spectra (10 m from UAG TGB)

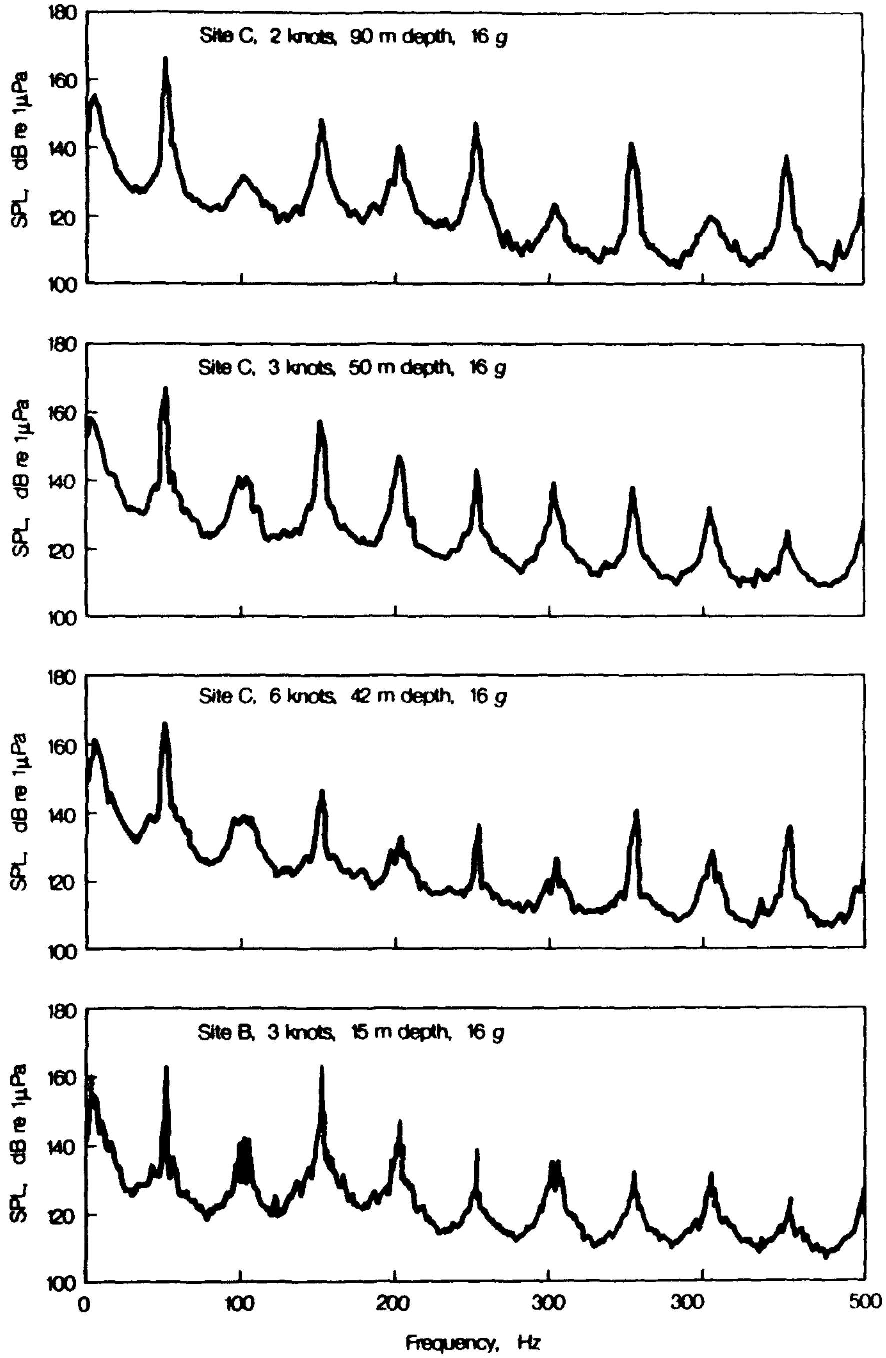

Figure 8: *100 Hz Sound Pressure Spectra (10 m from UAG TGB)*

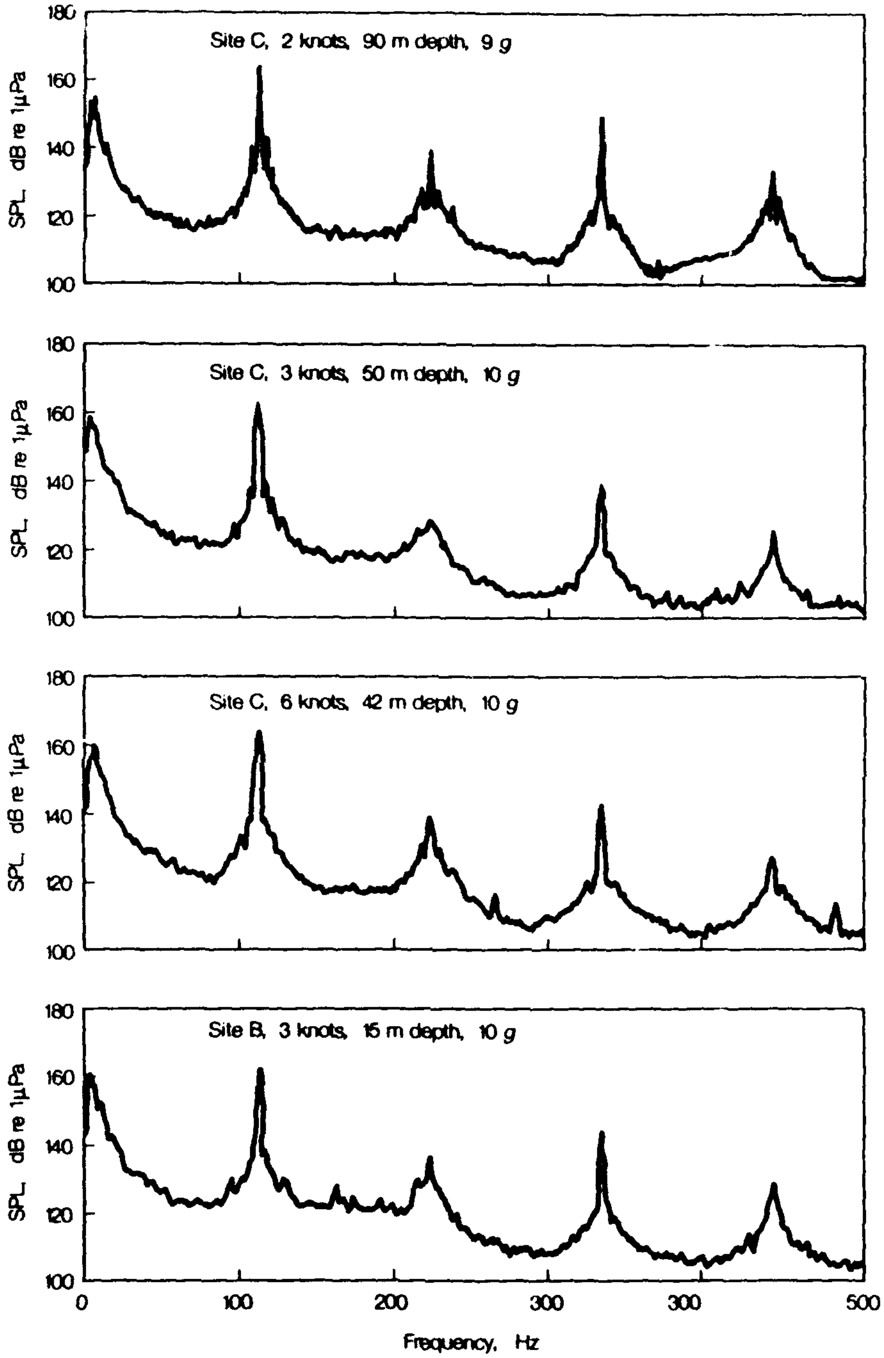

Figure 9: 220 Hz Sound Pressure Spectra (10m from UAG TGB)

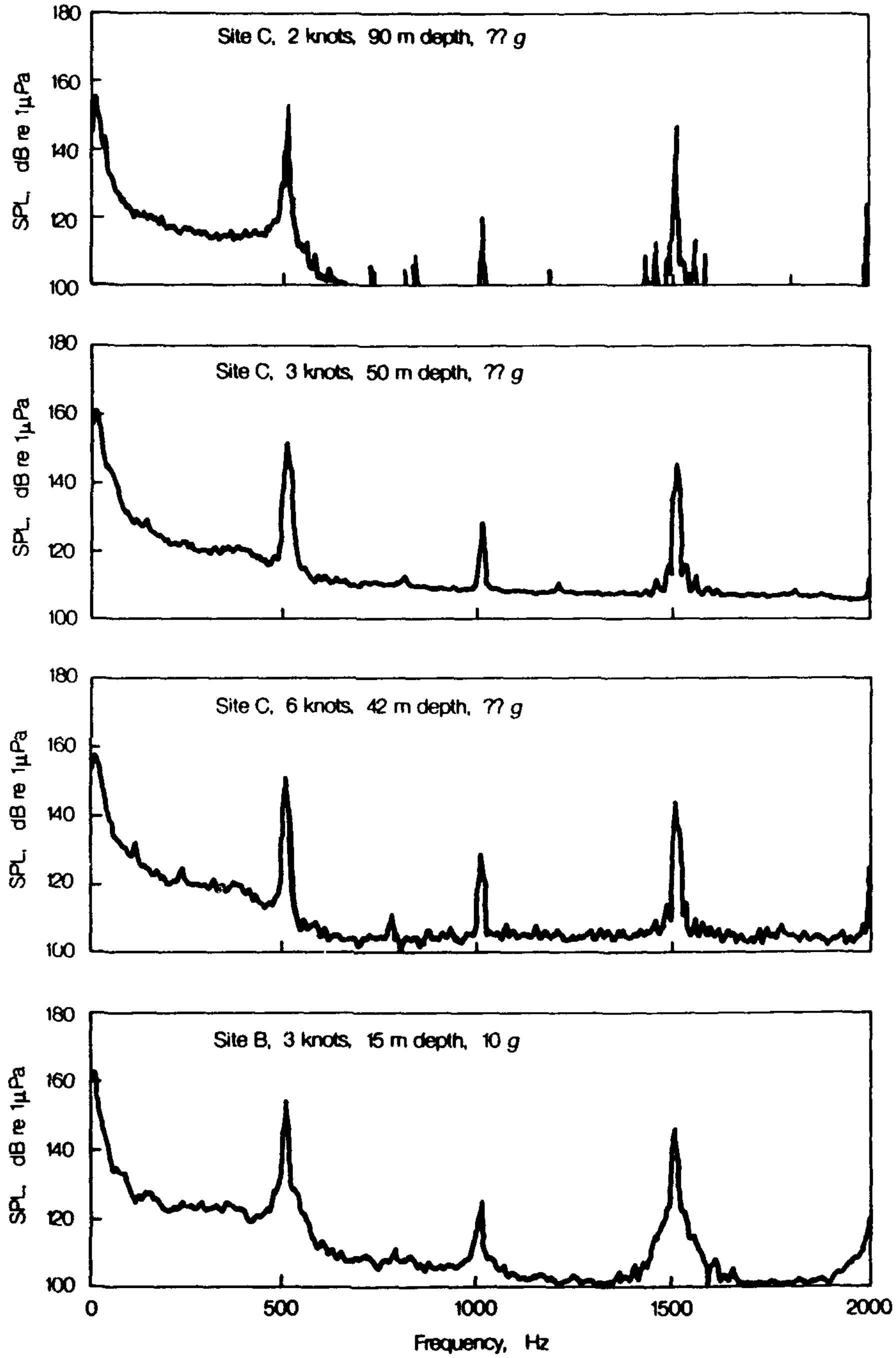

Figure 10: 500 Hz Sound Pressure Spectra (10m from UAG TGB)

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ABSTRACT

In support of a joint ALO-SA, DSTO, and Industry program to develop a discrete low frequency towed underwater acoustic generator (UAG), a series of sea trials were conducted. These trials were conducted in the Gulf of St. Vincent and the sea west of Kangaroo Island to check the environmental and acoustic performance of a concept UAG. This report describes the UAG Phase 2 evaluation trial held in March 1992. Details and results of the trial are provided along with an assessment of the UAG performance and conclusions and recommendations for further development and tests.

Underwater Acoustic Generator Phase 2
Sea Trial, March 1992

R. Alksne

(MRL-TN-640)

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